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The Variable Taste Perception of Sodium Benzoate[a, b, c]

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TASTE BLINDNESS to phenylthiocarbamide (PTC) *(2)*, which refers to the fact that PTC, while intensely bitter to most people, is practically tasteless to others, was discovered by A. L. Fox, a chemist, about 30 years ago. The validity of this phenomenon has been well established *(1)*. In 1954 Fox reported having found an analogous effect with sodium benzoate *(3)*. He claimed that there are marked individual differences in the qualitative taste response to sodium benzoate and that people can be reliably classified into "sweet," "salty," "bitter," "sour," or "tasteless" groups. He reported further that, when his test population was cross-tabulated on the basis of responses to both sodium benzoate and PTC, he found a definite relationship to food preferences. He suggested that this joint classification could be used for selecting flavor testing panels, so that their preferences would closely approximate those of a known population.

Verification of Fox's theory would have a significance even beyond the practical implications for panel selection. Tracking down the physiological basis for such consistent differences between people in taste perception would contribute important basic information toward developing a theory of the taste sense. All reports agree that individuals vary considerably in their taste responses to sodium benzoate, and similar effects have been reported for various other chemicals *(5)*. Usually the investigators have assumed, just as Fox did, that differences were physiologically determined.

Fox's paper stimulated a good deal of interest among food technologists, who are constantly seeking short-cut methods, and brief reports of his findings appeared in various technical publications and trade journals. However, in spite of the wide interest, but little further work has been done, either to verify his findings or to apply them. Hoover *(4)* did attempt to recheck Fox's work. He found that responses were extremely variable and concluded that the classification scheme was invalid. Exploratory experiments run at this Institute and at other laboratories, using water solutions of sodium benzoate as the stimuli, also gave results that were not consistent with Fox's theory.

So far the nature of the sodium benzoate effect has only been roughly indicated. Fox assumed that the variability is based on genetic differences, and this cannot be completely rejected; however, his experiment neglected certain important facets of the problem. Fox and others have used filter paper, impregnated with solution then dried, as the taste stimulus. The filter paper itself is not entirely flavorless and, even if it were, it might mechanically interfere with taste perception. Further, we must suppose that the effective strength of the stimulus could vary with the amount and pH of the subject's saliva. Further, even though the data were adequate, the interpretation might be faulty. The sensory experience aroused by sodium benzoate may be common among all persons, yet responses may be variable because the taste is unfamiliar and ambiguous so that the response is mediated in large part in the central nervous system, where it is influenced to a large extent by attitudes and expectations.

Problem. Exploratory experiments were required to narrow the range of possible explanations by describing the phenomenon more accurately. The present investigation was directed toward this end, being concerned, first, with the basic question of whether the response is variable and, secondly, whether variability, if found, is primarily a function of differences among people or differences in stimulus strength. The following hypotheses were set up:

(a) The qualitative gustatory response to sodium benzoate is no more variable than are responses to many common substances.

(b) The qualitative response to sodium benzoate varies among individuals in such a way that they can be reliably classified into a limited number of qualitative groups.

(c) The qualitative response to sodium benzoate varies as a function of stimulus strength.

METHOD

Test subjects. Test subjects were employees of this Institute—both men and women—most of whom had had previous experience in sensory testing, including psychophysical experiments which required judgment of fine differences. For several months prior to the experiment they participated in various exploratory studies on sodium benzoate, including threshold determinations, and were familiar with its taste.

Test materials. The stimuli were solutions of C. P. sodium benzoate made with distilled water which had been filtered through activated charcoal. Thresholds, established by the method of constant stimulus differences, were found to be quite different among the test subjects, ranging from .008% to .400%. A series of concentrations was finally selected to cover

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[b] This paper reports research undertaken at the Quartermaster Food & Container Institute for the Armed Forces, and has been assigned number 1008 in the series of papers approved for publication. The views or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the views or indorsement of the Department of Defense.

[c] Presented at the 19th Annual Meeting of the Institute of Food Technologists, Philadelphia, Pennsylvania, May 19, 1959.

the range from near the threshold for the most sensitive subjects to the point where the flavor was strong enough to be definitely unpleasant. The concentrations were spaced in the log series: .01%, .03%, .10%, .31%, and 1.00%.

Test method and procedure. The Flavor Analysis questionnaire (Figure 1) was used to rate each sample for intensity of

FLAVOR ANALYSIS

Name_____ Date_____

INTENSITY

Sample Code_____

	none	slight	moderate	strong	extreme
Sour					
Salt					
Sweet					
Bitter					

Figure 1. Questionnaire for flavor analysis tests.

each of the 4 qualities: salt, sweet, sour, and bitter. The instructions given to the subjects describe the detail of the test: "Your task will be to analyze the flavor of each sample. You will do this by indicating the strength of each of the qualities, —*salt, sour, sweet,* and *bitter,* on the questionnaire forms provided. Use a different form for each sample. Please consider and rate the qualities in the order in which they appear on the questionnaire. You will have all the time you need to consider each sample and you may taste it as often as you wish. Ask for more of a solution if necessary. Return the glass as soon as you finish a sample and rinse your mouth thoroughly with water. There will be a one-minute wait from the time you return one glass until you receive the next sample. There will be 5 samples in all.

These are water solutions of sodium benzoate. This material is not harmful; however, you are asked to spit out the solution rather than swallow it in order to reduce carry-over effects from one sample to the next."

The same questionnaire was used to estimate total flavor intensity by asking for a single rating of over-all intensity without attempting to break it down into the separate qualities.

Experimental design. A subject judged all 5 solutions at each session. The 120 possible different orders of presentation were assigned randomly to test subjects to balance order effects insofar as possible. The 24 possible orders of appearance of the 4 qualities on the questionnaire were also balanced and were used as nearly as possible with equal frequency. Sessions were conducted at about weekly intervals. There were 2 replications of the experiment. The first involved a total of 5 sessions. The second replication was run 9 months after the completion of the first and involved only 2 sessions for each subject. Of the 25 subjects who participated in the first series of tests, only 18 were available for the second. Rating of over-all flavor intensity was done by the 25-member panel soon after the first replication of the flavor analysis.

Data analysis. The data were subjected to several analyses of variance. The analysis reported here involved only mean rating, i.e., the average, for each subject, of the ratings given to each sample for each quality. Data were used only from the 18 subjects who participated in both replications. The error terms for determining reproducibility of results were as follows: each main effect was tested against the pooled variance from all interactions involving replication and the particular effect; replication main effect itself was tested against the pooled variance from "subject" and the subject-replication interaction; and interactions were tested against the pooled variance from all higher order interactions involving the same factors.

In analysis of the main experiment the factor of concentration was given special treatment, being broken down into four independent comparisons. The reason for this approach, and the comparisons themselves, are discussed below.

RESULTS AND DISCUSSION

Figure 2 plots the relation of over-all flavor intensity for the 5 samples against concentration. Two points may be noted. First, the two weakest concentrations rated the same, and second, beyond this point the function is linear.

In Figure 3 the average intensity ratings from the flavor analysis experiment have been plotted against concentration separately for each of the four qualities.

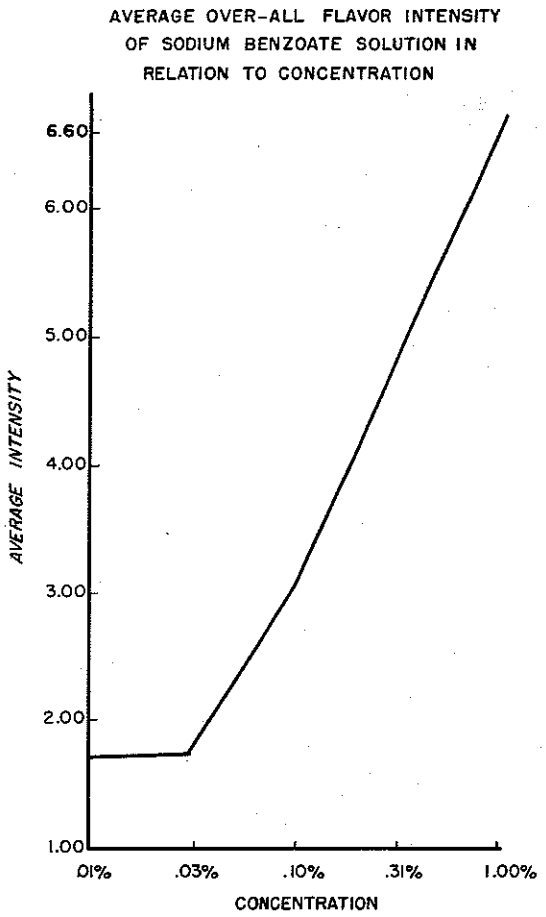

Figure 2. Average over-all flavor intensity of sodium benzoate solution in relation to concentration.

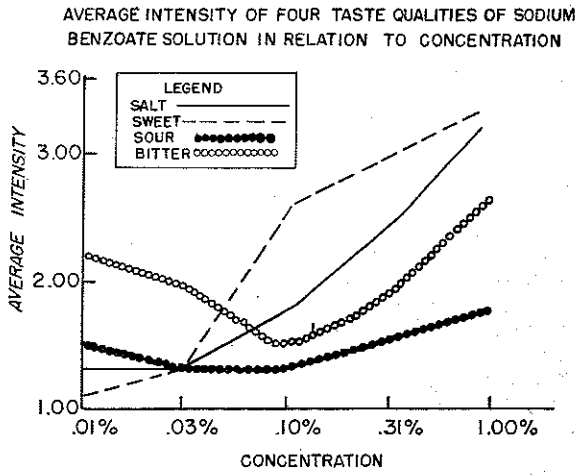

Figure 3. Average intensity of four taste qualities of sodium benzoate solution in relation to concentration.

These plots are based on the average ratings over both replications of only those 18 subjects who participated in both. Results are not shown separately for the replications because the 2 charts were closely similar. At the two low concentrations, the average ratings were practically identical; however, for the higher concentrations, the *salt, sweet* and *sour* averages were somewhat higher in the first replication. This is reflected in the significant interaction between replication and concentration—Comparison B.

Although these plots start at about the same level as that for over-all intensity, they do not rise to the same level at the highest concentrations. Of course, in the flavor analysis the subjects had a quite different and more difficult task than in rating over-all intensity. Note that the curve for bitter differs from the others. It starts at a definitely higher level and has its minimum at the middle concentration before again ascending. The higher level of bitter at the lowest concentrations appears to be unrelated to sodium benzoate, since many of the subjects judged the distilled water itself to be bitter.

The general level of intensity, considering all qualities, is the same for the two weakest solutions, which agrees with the results on over-all intensity. This confirmed that we had, in effect, included two "base line" or "zero" samples in the experiment. Since this would tend to cause spuriously high interactions of concentration with quality, a method of handling concentration was adopted which avoided this. Concentration was broken down into the following orthogonal comparisons:

Comparison A—difference between the two weakest concentrations.

Comparison B—the two weakest *vs* the three strongest concentrations.

Comparison C—linear effect among the three strongest concentrations.

Comparison D—quadratic effect among the three strongest concentrations.

Table 1 extracts from the analysis of variance those figures which are important to the present discussion. The higher order interactions, most of which were insignificant or borderline, are not shown separately.

The main effect of replication is not significant, which indicates that the average level of rating was the same both times. This speaks favorably for reliability; however, the interactions of replication with subject, quality, and concentration Comparison B—were all significant at about the 1% level, which shows that there was some shifting between replications. The rank order of the subjects' average ratings changed to some extent between replications; also the differences between averages for the different qualities were not the same, although they fell in the same rank order in the 2 replications.

The significant main effect of subject was expected and reflects only people's differing levels of sensitivity and different habits of using the scale. The significant main effect of quality verifies what is obvious from Figure 3, namely, that the over-all level for some qualities is higher than for others. The various concentration main effects may be interpreted as follows: Comparison A is not significant, which verifies that the 2 weakest samples were essentially the same. The insignificant Comparison D effect shows the absence of quadratic effect among the top 3 samples. However, both Comparison B and Comparison C account for a high proportion of the total variance. Again, this was expected and simply shows that higher concentrations are rated as more intense.

TABLE 1

Analysis of variance for flavor analysis of sodium benzoate

Source of variance	Degrees of freedom	Mean square	Significance
Replication	1	12.30	....
Subject	17	10.00	<0.1%
Quality	3	18.65	<0.1%
Concentration Comparison A	1	.39	....
Concentration Comparison B	1	92.23	<0.1%
Concentration Comparison C	1	69.52	<0.1%
Concentration Comparison D	1	.56	....
Subject-quality	51	3.20	<0.1%
Concen. Comp. A—Quality	3	.76	1.0%
Concen. Comp. B—Quality	3	19.61	<0.1%
Concen. Comp. C—Quality	3	2.55	<0.1%
Concen. Comp. D—Quality	3	1.35	....
Interactions (2-factor) with replication:			
Repl.—Subject	17	1.53	1.0%
Repl.—Quality	3	2.58	1.0%
Repl.—Conc. compar. A	1	.10	....
Repl.—Conc. compar. B	1	9.00	0.5%
Repl.—Conc. compar. C	1	1.76	....
Repl.—Conc. compar. D	1	.26	....
Other 2-factor interactions with subject:			
Subject—Conc. compar. A	17	.32	5%
Subject—Conc. compar. B	17	1.95	....
Subject—Conc. compar. C	17	1.83	....
Subject—Conc. compar. D	17	.17	....
All 3-factor and 4-factor interactions combined	539	.87	

It is the two-factor interactions which are most important for this experiment. A significant subject-quality interaction would indicate that responses differ among people, and would tend to support Fox's original claim. A significant concentration-quality interaction, on the other hand, would indicate that the variable responses are a function of differences in strength of the stimulus. The analysis gives both hypotheses some support. Subject-quality interaction is significant at beyond the 0.1% level, as are also the interaction of quality with concentration Comparisons B and C. The mean square for the Comparison B-quality interaction is much higher than for either of the others but this is partly spurious. It shows that the relative order of the 4 qualities based on the average of the 3 strongest samples was different from the relative order based on the average of the 2 weakest, but we have already noted that the latter were so weak that the order of the qualities was probably due to chance. The 1% level of significance for the concentration Comparison A-quality interaction was probably due to the previously mentioned bitter responses to the distilled water and thus would have no bearing on the sodium benzoate problem. The interaction of quality with concentration Comparison C, however, reflects significant differences in the quali-

ties reported at different above-threshold concentrations, hence bears directly on hypothesis (c).

An important finding that emerged, not from formal analysis of the data, but from inspection of the patterns of responses for individual subjects was that almost all of them reported more than one quality. Some subjects consistently rated a given quality highest yet ascribed intensities to one or two others that were far above the negligible level; others would rate 2 or 3 qualities at about the same level, or their relative ratings of the qualities would be different for strong and weak concentrations. No reasonable scheme of classifying subjects according to their patterns of response could be devised, since there would have been nearly as many classes as subjects. One finding, however, is definite—sodium benzoate flavor is a mixture, or blend. Thus, any experimental technique which required report of a single quality would misrepresent the facts by forcibly discarding information.

Finally, we come to a question of general control. The results show that there is considerable variability in the taste response to sodium benzoate, but is this unusual? Perhaps such variability is characteristic of the taste response in general and not just of sodium benzoate. As a check on this possibility, comparable flavor analysis tests were run on caffein, sucrose, sodium chloride, and citric acid. The subjects were 19 of the original panel. The stimuli were log series of 4 concentrations of each substance, the weakest being set at a level just above the estimated group threshold. All 16 samples were included in the same experiment. The order of presentation was determined randomly for each subject and four sessions were required to test the complete set.

Results are shown in Figure 4, separately for each substance. The average ratings are plotted against concentration separately for each quality. Although some confusion is demonstrated at the lower levels, as concentration increases the single quality appropriate to the substance emerges and the others drop off to the "noise" level. Definitely there is much less variability than for sodium benzoate.

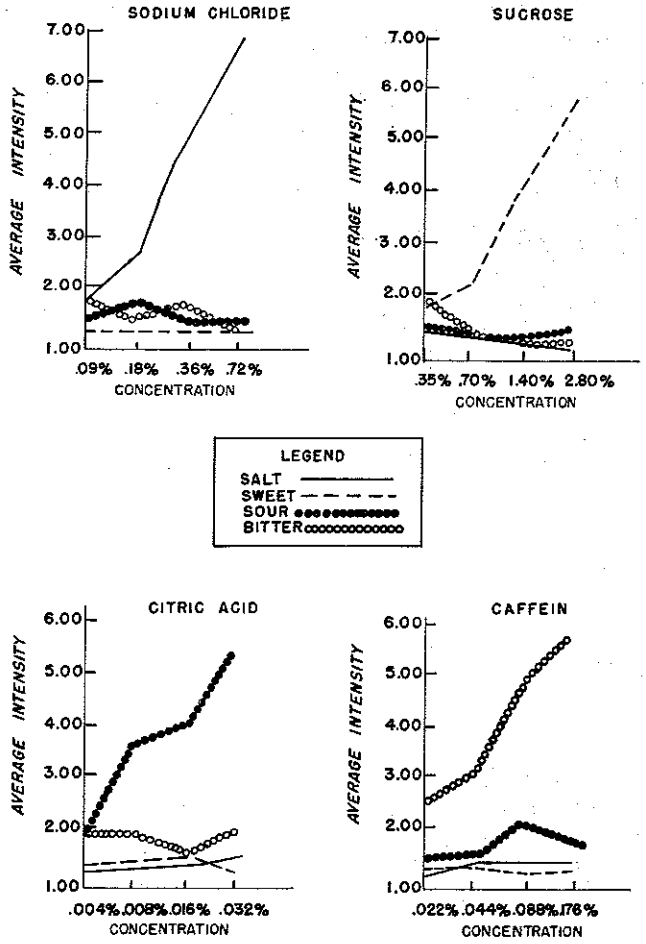

Figure 4. Average intensity of four taste qualities in relation to concentration for solutions of common substances.

CONCLUSIONS

Let us assess the results in terms of the hypotheses set forth in the introduction: The first hypothesis, that the response to sodium benzoate is no more variable than for many common substances, can be rejected on the basis of comparison with the flavor analyses of common substances. The second hypothesis can also be rejected, but only because it overstates the case. We have confirmed that responses vary among individuals, but our data strongly suggest that such responses would not be a reliable way of classifying people. The simple statement of the third hypothesis is confirmed in that responses were shown to vary as a function of stimulus concentration, among other things.

The results of this study are not definitive in the sense that they completely "explain" variation in the taste response to sodium benzoate. The variation has been confirmed and we have briefly explored some of the characteristics of the phenomenon. Definitely, it would appear that any simple model will not serve. Fox implied that the differences in perception were due to basic physiological differences. This may be partially true; however, once it is seen that we are dealing, not with a simple 5-category classification, but with a complex set of patterns, it is reasonable to look for multiple causes. Some of these may be physiological, but it is also likely that much of the variation is related to differences among people in learning and verbal habits, specifically the language they use to describe their taste experiences.

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